The Governance of Polycentric National Infrastructure Systems: Evidence from the UK National Infrastructure Plan

For much of the 20th century - with the commitment of western societies to the pursuit of the welfarism of the `positive' state - how states infrastructured [1]reflected an endemic belief in market failure (Majone 1997). This was encapsulated within the `infrastructural ideal' where infrastructure systems were formed around monolithic, non-discriminatory notions of universality and ubiquity (Graham and Marvin 2001). State infrastructure strategies were realised through a process of centralized control to enable the state to form and sustain the relations between the state, business and civil society necessary to territoriality (Mann 1984). In this article, territoriality is defined as those actions undertaken (in this case by the state) within its bordered, demarcated space that allows the state to control and secure particular outcomes within that space (Taylor 1994). State infrastructuring as a method of territoriality is reflected within what is termed here its `infrastructural mandate'. This mandate reflects the state's capability to develop and sustain an infrastructure system that enables it to economically, politically and socially control, integrate, secure and develop its bounded space (see Mann 1984, Taylor 1994). As identified within the literature on large technical systems (see Hughes 1983), this mandate depends upon both the provision of standalone and interconnected physical structures (i.e. hard infrastructure) and the technical, social and institutional factors that create, sustain and maintain the infrastructural relationships necessary to state territoriality (i.e. soft infrastructure).

The erosion of welfarism and the emergence of neo-liberalism in policy strategies have shifted the notion of how states infrastructure towards market based systems (Auster and Silver 1979). Under such systems, the infrastructural mandate is - at least partially - delegated

[1] Infrastructure is defined here as the `pervasive enabling of resources in network form' through the provision of supporting physical transmission and organizational systems (Bowker, Baker et. al 2010 p.98))

to non-state actors. This reflects a discontinuity between the state's need to infrastructure and its direct capability to undertake infrastructuring. Such discontinuities have fed the rise of polycentrism within infrastructure systems. In this context, polycentrism reflects that the state becomes but one actor within the infrastructure system where nominally independent components under diverse ownership exhibit interdependence (Ostrom, Tiebout and Warren 1961). This polycentrism has reshaped infrastructural governance[2] as infrastructure systems form through a multitude of independent, semi-independent and interdependent actions. The state will seek to manage these processes to meet its infrastructural requirements simultaneously with the needs of non-state actors (Scholte 2005, Ostrom 2010). It is the analysis of these governance processes - as a means of enabling the state to meet its infrastructural mandate - that forms the core of the research objective of this paper.

In attempting to understand how a state reconciles polycentrism with its infrastructural mandate, this article focuses on the National Infrastructure System (NIS). The NIS is the totality of networked economic infrastructure (i.e. telecoms, energy and transport) within the borders of a state but which exhibit globality (see below). This globality recognises that NIS are embedded within (and interact with) the international economic system (Johnson and Turner 1997). Integral to the operation and evolution of the NIS is the spatial and functional complex relationships and interdependencies that exist within and across its component infrastructures (Larner and Walters 2004, Estache and Fay 2007). This systemic approach signals that infrastructures are hierarchical, complex systems that need to be defined broadly to indicate the diverse tangible and intangible components that can impact on infrastructural

[2] Infrastructural governance is defined here as the informal and formal processes and institutions that steer the evolution of infrastructure (after Keohane and Nye 2000)

performance (Hughes 1983)[3]. This perspective is set within a governance system which is evolving to allow the state to cede control and ownership of the NIS whilst seeking to influence the outcomes of a more complex system. In developing a polycentric approach to infrastructural governance, this article examines the forces of evolution within polycentric economic infrastructure systems and synthesises multiple streams of research from information studies, political economy and human geography on infrastructure to identify the key governance issues within polycentric NIS. Thereafter these themes are explored with reference to UK's infrastructuring process embodied within the National Infrastructure Plan (NIP) which was launched in 2010.

The Governance Structure of National Infrastructure Systems

The rising public policy emphasis on the NIS is a reflection of growing practitioner and academic discourse on an aggregated treatment of infrastructure as means to understand it as a tool of state territoriality (see for example Hall et. al 2012). This has had its most notable expression in widespread adoption of National Infrastructure Strategies by many OECD members. Such strategies seek to offer a holistic framework for state infrastructural evolution (OECD 2007, a, b). In practice, NIS are formed retrospectively with the functional/spatial coalescence of sectors that were on previously independent trajectories becoming dependent upon and embedded within other infrastructures (see for example Rinaldi et. al 2001). Moreover these infrastructures will have other infrastructures embedded within them (Hall et al 2012). The multi-disciplinary literature on infrastructure is coalescing around a consensus that aligning a polycentric NIS to the needs of state territoriality is based on the interaction

[3] Hughes (1983) arguably set the precedent for the application of systems thinking to infrastructure. This argues that infrastructures need to be perceived in a holistic sense rather than merely as the sum of its components. This approach has proved especially pertinent in the field of Critical Infrastructure research.

between and within the NIS' hard and soft infrastructure sub-systems (OECD 2007a,b, Hall et. al 2012).

Themes in Hard Infrastructure Governance

The governance of the hard infrastructure system – which lies at the core of the NIS – has been shaped by the consequences of technological, institutional and commercial change which have morphed its conceptualization towards more complex treatments. The literature on infrastructure governance can be coalesced around three (inter-related) forms of complexity - structural, spatial and operational – which are embedded within polycentric infrastructure systems.

- *Structural complexity*: this is indicative of a multi-layered, hierarchical infrastructure system with polycentric ownership and control. As reflected in table 1, the hard infrastructure component of an infrastructure system (i.e. the network of networks) is conceived as the aggregate of modular; composite and network infrastructure. This multi-layered, hierarchical approach underscores that the hard infrastructure system forms and evolves under complex interactions within and between these layers. This reflects how the progressive liberalization of the infrastructure value system (see for example Allee 2003) and its consequent fragmentation in terms of structure, ownership and control impacts on system form and function (Orr and Kennedy 2008, Kothandaraman and Wilson 2001). This pattern of structural complexity reveals how the system is being shaped by the range of agents especially at the composite and network levels. This includes not just privatized incumbents but also global investment funds (see Torrance 2009 for an overview), trans-national infrastructure

corporations (UNCTAD 2008), pension funds and foreign governments (see Clark et al 2013). At the modular and composite levels, this fragmentation has been compounded by freer markets in infrastructure/access technologies, internationally accepted modular standards and more open access to the infrastructure system (see for example Garud and Kumaramaswamy 2003). These processes of polycentrism find their most extreme representation in the existence of inverse infrastructures (Zio 2007, Egyedi et al 2012).

Table 1: The Multiple Levels of the Hierarchical National Infrastructure System

System Level	The network of networks within a demarcated space (i.e. the state).
Network Level	The totality of interacting composite public and private infrastructures within a defined economic sector (i.e. energy, transport or telecommunications).
Composite Level	These are public and private infrastructures configured to meet a specific function through a unique configuration of modules.
Modular Level	These are standardized infrastructural components that can be flexibly deployed and re-deployed to create composite infrastructures.

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- *Spatial complexity*: this reflects a duality of processes. The first that NIS are open systems formed of a configuration of national and international resources and capabilities at network, composite and modular levels. This structural globality is highlighted by the emergence of trans-national infrastructure corporations (UNCTAD 2008), specialist infrastructure funds (see for example Weber and Alfen 2010) and sovereign wealth funds or other agents (Orr and Kennedy 2008). The second is that

NIS operate as part of a global network of national systems. This operational globality reflects the policy narratives shaped by the logic of the competition state (Cerny 2010) and its focus on connectivity and network effects (Economides 2006). These processes embed globality within NIS shaping discourses on competitiveness (see for example Glykou and Pitelis 2011, Rodrik et. al. 2004) and multi-level operational interdependencies. Such processes reveal that - whilst hard infrastructures are territorially fixed - the activities that occur over them (or affect their ability to act as infrastructure cannot be reducible) to that point in space where they are used. In addition, they identify that the effects of an NIS are not spatially specific (Massey 1993, Johnson and Turner 1997, 2005, Alonso-Villar, 2005, Bougheas et.al, 2003). This covers infrastructure that are dis-located but which can (or have the potential to) impact on each other through both implicit and explicit channels subject to the lag effects created by the degree of dislocation. Spatial complexity suggests that – largely through cyber interdependencies – these lag effects are falling to the point of simultaneity.

- *Operational Complexity:* within polycentric NIS this reflects the reciprocal relationships - both complex and linear - between both parallel and discrete infrastructures. This reciprocity is based on the extremes of co-location and/or simultaneous use or – at the other end of spectrum – dislocated systems subject to lagged effects of usage by one party on another. Such processes can make system performance unpredictable and render vulnerabilities discrete (for an extensive review of the subject see D'Agostino & Scala 2014). Operational complexity reflects a mutual embeddedness of infrastructure (both spatially and structurally) that should one layer or co-/dis-located system fail other parts can also fail to operate. Rinaldi et. al (2001)

identify that the operational interdependencies emerge from physical, cyber, geographic and `logical' dependencies. This is reinforced by the literature on large technical systems (see for example Hughes 1983) where such dependencies run from the fixed assets to those (such as in transport with vehicular capacity) that can be deployed across the system in different spatial points as well as institutional frameworks that shape their development (see below). The literature has tended to focus on the study of operational complexity where usage depends on co-consumption of other (both proximate and distant) infrastructures (Macualey 2010, Hokstad et al. 2012).

The embedded complexity of polycentric NIS can impact on the capability of state infrastructuring through generating a system that is fragmented, effected by extra-territorial events and processes (Johnson and Turner 2005) and whose performance (especially with regards to the needs of territoriality) can be difficult to predict.

Themes in Soft Infrastructure Governance

Embedding and securing the needs of territoriality within a polycentric NIS depends upon the `steering' capabilities of the state. The `steering' of the NIS is done through what has come to be termed the soft infrastructure system. The literature indicates that these `steering' capabilities can be synthesized into three themes: sustainability, consistency and criticality (Ghosh and De 2005, Batten and Karlsson 1996, Canning and Bennathan, 2000; Kirkpatrick et al 2006). `

- *Sustainability:* In this context, sustainability refers to the capability of the polycentric system to facilitate the emergence of self-sustaining infrastructural business models[4] that support the construction and operation of those infrastructures that facilitate state territoriality (Stubb and Cocklin 2008, OECD 2008). Sustainability in public infrastructure system has traditionally been hindered by the financial risk and temporal profiles of hard infrastructure investment (for a review OECD 2007, Gil and Beckman 2009, Flyvberg 2007). In this context, the soft infrastructure system has to militate against these risks either through the regulation of prices/revenue, market structure or via the allocation of risk between the state and the non-state investor through policy devices such as public-private partnerships (PPPs) (see Kwak et al 2009).

- *Consistency:* this stresses that soft infrastructure systems need to reconcile the temporal inconsistencies between public and private needs within the evolution/formation of the polycentric NIS. Under welfarism, time inconsistencies could be reconciled through state ownership (Graham and Marvin 2001). Within a polycentric NIS, the sustainability of business models built on long term investment timeframes are vulnerable to the nuances of short term political cycles. Reconciling these temporal inconsistencies requires consistency in policy frameworks across the political cycle (Chari et. al. 1988). To militate against this inconsistency between political and investment cycles, a number of states have moved to explicitly depoliticise the process of infrastructure formation through the establishment of

[4] The literature on business models is a burgeoning one (see for example Osterwalder et al, 2005) each of which offer similar definitions on the form and nature of business models. The definition used here is of businesses as `self-sustaining commercial systems' reflecting the capability of the firm to offer a value proposition that enables the firm to generate sufficient financial resource to ensure commercial sustenance which is based on a reconciliation of the firm's operational and marketing components (Schafer et al 2005).

independent infrastructure boards (see Besley et al. 2013). This consistency has been driven by unanimity around the desire of the state to stimulate and sustain resource flows (both financial and non-financial) into the NIS and of the realisation that this lies beyond its sole competency. Nonetheless, polycentric infrastructure systems are subject to pre-ordained caveats over operational obligations and legitimisation processes. State activism is still likely to be stimulated under conditions of market failure or for projects of national significance (Niskanen 1991).

- *Criticality:* this is created by the centrality of specific infrastructures to territoriality. More especially where infrastructure failure would risk or undermine state capability to influence outcomes within a territory (see for example Brown, et al. 2006, Lewis 2014). The state's perspective on the salience of - and risk within - designated critical infrastructures informs both issues of time consistency and sustainability through defining the parameters of state action (Rinaldi et. al 2001). Critical infrastructure policies can legitimize state control or expropriation of key - privately owned - infrastructures under pre-ordained circumstances (such as the commercial failure of the operator or security concerns) (Braithwaite and Drahos 2000, OECD 2008). The efficacy of state discretionary acts is challenged by transnational system interdependencies suggesting that criticality has to be reinforced inter-state co-ordination (Hammerli and Renda 2010).

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These themes within hard and soft infrastructure reflect that the governance of polycentric NIS is focused on steering a complex system towards the meeting the needs of the territorial state. The state's steering function has a dual emphasis of not only seeking to create tipping points to stimulate the evolution of the system but also has the capacity to militate against

`dampening processes' which limit or skew system development (see Davies et al. 2010). The governance of `dampening' reflects that NIS can be subject to the forces of senescence and obsolescence as the system fails to respond to – and/or becomes divorced from - its economic and social contextual drivers (see Hall et.al 2012). NIS governance also seeks the avoidance of complexity catastrophe where infrastructure systems grow so complex (both within and across political borders) they become difficult to govern. Across economic infrastructure, business models are bound by the centrality of traffic generation to system operational sustainability (in the absence of large scale state ownership/support). However spatial and temporal variations in traffic (relative to high up front fixed and sunk costs), the apportioning of risk between parties and the temporal lag between project initiation/construction (and the risks within this phase) and operation can work against sustainability. To explore how the structure and form of the polycentrism within the NIS is governed to shape the needs of the state, the experience of the UK NIS since the introduction of the NIP in 2010 is examined[5].

The UK NIS and the National Infrastructure Plan

The transformation in the governance of the UK NIS over the past four decades has been widely acknowledged (see for example Stern 2014). A major legacy of this transformation has been the shift towards a more structurally, spatially and functionally complex infrastructure system. Path dependencies shaped by the progressive liberalisation and privatisation of the UK NIS since the 1980s (for a review see Hall et al. 2012) have eroded the positivist state's strong welfarist approaches that dominated UK infrastructure strategy for much of the post-war period. Moreover these processes have steered the NIS towards a more

[5] In 2016, the NIP was replaced by the National Infrastructure Development Plan (NIDP) under the auspices of the Infrastructure Project Authority (IPA 2016). Despite a more ambitious project pipeline, the NIDP reflects continuity with the NIP through embracing the same core principles and strategies.

market-based polycentric structure (Helm 2009). This transformation in governance has coincided with a consensus amongst both government and business that the UK has persistently under-invested in its public infrastructure. A plethora of reports (see for example CBI 2013, Helm et. al 2009 and TIF 2002) highlighted the scale of the under-investment where investment in public infrastructure fell from 8 per cent of GDP in 1970s to 1.5 per cent in the 2000s (see CBI 2013). The UK Treasury's own figures – at the launch of the NIP - estimated that the UK needs to invest £ 250 bn to 2018 to overcome systemic risks and emergent deficiencies (HMT 2010 a,b).

To counteract this trend –and against a background of public sector austerity and public policy discourses on growth (TIF 2012) – the UK government (in 2010) launched the National Infrastructure Plan (NIP). The plan integrated a series of pre-existing (45 per cent of the 480 projects within the plan predated the NIP) and new hard and soft infrastructure projects (80 per cent of the projects were focused on soft infrastructure) into a single over-arching strategy to raise UK investment in its NIS to 3 per cent of GDP by 2015 (double the rate of 2010) (HMT, 2011, 2012). The plan targets specific segments of the UK NIS through the prioritisation of hard (economic) infrastructure investments to be delivered largely by private finance sustained by user charges. Overall, the Treasury estimates that 70 per cent of the finance for the projects will be privately sourced (up to 2020) (HMT 2011, 2013).

Embedded within the plan is the logic of the competition state through policy narratives focused on `infrastructure as a growth catalyst' (Cerny 2010). This shift in policy discourse is manifested through a swing away from investment in social infrastructure towards economic infrastructure (HMT 2010b). The Government seeks to utilise the NIP as a catalyst to generate a longer term broad re-infrastructuring of the UK. This involves re-orientating,

adapting and adding to the pre-existing stock of infrastructure (militating against the risk of system senescence and obsolescence) to reflect shifting demands upon the NIS (Hall et al 2012). The micro-economic interventionism of the NIP sought to drive a `sustainable polycentrism' model of infrastructure development within the UK NIS. The `sustainable polycentrism' model is based on promoting and expanding non-state involvement in the UK NIS through facilitating sustainable infrastructural business models in those segments of UK system targeted by the NIP. This model of NIS development is based on the state seeking to create coalescence between public and private interests through reform of the infrastructural governance system (Stern 2014).

Towards `Sustainable Polycentrism' in the UK NIS

`Sustainable polycentrism' is underscored within public policy discourse on the NIS as a non-discriminatory polycentric system. This reflects a political consensus that the UK can only realise the NIP through creating an open system in terms of infrastructure ownership and control. Over the past three decades, the UK NIS has attracted substantial financing from both domestic and international sources through the opening up of the public infrastructure value system. This has extended non-state involvement in the NIS beyond its conventional role of construction towards infrastructure planning, maintenance, finance and management. As table 2, indicates by the end of 2014 (from figures updated from an OFT dataset 2010), 60 per cent of the UK's public infrastructure was in private ownership with 38 per cent owned by overseas investors[6]. Much of this investment has been directed towards equity (i.e. buying shares in public limited companies with a substantial infrastructure asset base) and

[6] Despite this trend, these statistics say little with regards to market structure. In fact, many of the privatized networks are still characterised by dominant (ex-state owned) incumbents. These ex-state owned businesses have been the focus of infrastructure investment by both domestic and overseas investors

brownfield investment (i.e. investing in pre-existing infrastructure asset) rather than the greenfield investment (i.e. the financing of new build infrastructure) prioritised by the NIP. Indeed of the £15 billion invested in the NIS since 2010 (and up to 2014), 80 per cent has been in the form of equity investment (UK TI 2014). Greenfield projects between 2011 and 2015 were still largely financed by the state with the UK government providing up to two-thirds of funding (ICE 2015).

Table 2: The Ownership Structure of the UK NIS
(% ownership) (as of 2015)

	Private	**Public**	**Foreign PLC**	**UK PLC**	**Not for profit**
Airport	46 of which: - Infrastructure fund 13 - Sovereign Wealth Fund 9 - Investment Fund 13 - Pension Fund 5 - Private Equity 3 - Other 3	20	32	2	0
Energy	11 of which: - Bank 2.1 - Infrastructure fund 4.2 - Investment Fund 1.2 - Pension Fund 3.3 - Private Equity 0.3	4	33	52	0.3
Ports	57 of which: - Individual 3 - Infrastructure fund 29 - Investment fund 7 - Private limited 6 - Sovereign Wealth Fund 12	5	8	10	20
Telecoms	2 of which: - Infrastructure fund 1 - Pension fund 1 - Investment fund 0.3	0	0	98	0
Rail	0.3 (breakdown unspecified).	49.2	0.2	0.1	50.2
Tolled	62.2 of which: - Infrastructure fund 41.2 - Other private 10.6 - Individuals 0.4	33.9	12.9		0.9

Adapted from OFT 2010

Despite the strategic intent, the UK NIS is not a fully open system (there do remain limited restrictions on infrastructural ownership and control derived largely from European legislation (see Hall et al 2012)). Despite this the UK NIS has increasingly developed in a meta-national direction drawing on a global pool of investment funds, infrastructural capabilities and know how (OFT 2010). As conventional bank-based sources of infrastructure finance dried up in the aftermath of global financial crisis (NAO 2010, 2015) so the UK government sought to diversify infrastructure funding via engaging with overseas Sovereign Wealth Funds from China, Kuwait and Qatar as well as the state backed Japanese Bank for International Cooperation. By 2014, investment by overseas investors follows the broad market trends of focusing on buying into the equity of the pre-existing system and not greenfield projects (UK TI 2014).

Domestically, the state has also worked to draw in UK Pension Funds into the NIP where these funds have – historically - not invested more than an average of 1-2 per cent of their portfolio in infrastructure assets (Della-Croce 2012)[7]. By 2010, UK Pension funds had only committed £2bn of £1tn of assets under their management to UK infrastructure (HMT 2013). By 2020, the UK government seeks to raise around £ 20 billion into NIP related projects from Pension Funds though, by the end of 2014, the sector had only committed to 5 per cent of this target figure (NAO 2015). The reticence reflects a desire to avoid construction risk and therefore by-pass Greenfield investment. Indeed of the £330 million committed by the Autumn of 2014, none was directed to new projects.

[7] This was enabled through the creation of the Pensions Infrastructure Platform in 2011 which pooled a number of public sector funds to channel funds into UK Infrastructure. More latterly this has been joined by the GLIL fund (established in 2016) which is a rival scheme comprised of five of the UK's largest local government pension funds.

The Limits to `Sustainable Polycentrism'

In practice, polycentrism is highly variable across the UK NIS. Some sectors have business models built around state regulation (most notably the major backbone infrastructure still being under the control of large ex-incumbents) (see table 3) to either militate against the effects of natural monopoly and/or to ensure the necessary investment in the system (see for example Stern 2014). In terms of the NIP, this variable polycentrism can run counter to the open system strategy which is meant to drive the evolution of the NIP. This has had its most obvious manifestation where incumbents have been successful in securing state-funded elements of the NIP. This has been exemplified by the case of BT (the incumbent telecommunications operator) facing little competition when winning the rural broadband contract (NAO 2013a). It was also evident in the energy sector where incumbent control and rising user charges that have led to issues over the funding of infrastructure (Helm 2012). As proximity matters in infrastructure, a polycentric market structure does not mean that assets are substitutable (for example ports may specialise in specific types of cargo (OFT 2010)). In the case of concessions or franchises, the state may promote exclusive rights where polycentric structures are unlikely to deliver the desired investment.

Table 3: Sector network structure and regulatory form

	Energy	**Telecommunication**	**Transport**
Services	Polycentric system across gas, electricity and oil. Gas and electricity are controlled via regulation	Polycentric operation though subject to universal service obligations. Fixed and mobile	Polycentric across maritime, air, land-based transport. Subject to legitimization
Nodes	Generation – polycentric system based round six generators; regulated private ownership in gas and	Private exchanges alongside regulated access to incumbency	Ports: – privately owned; competition between ports both domestically and with overseas

	electricity	resources	ports. Airports: private and polycentric system – especially at regional level. Key national hubs regulated.
Links	Backbone – controlled by National Grid – regulated cash flows with government support Local access networks: price regulated regional monopolies	Backbone - polycentric but with regulated cash flows and targeted government support Fixed local loop - strong control Mobile – polycentric – network sharing	Road – largely state owned with limited private involvement Rail: state owned and regulated cash flow and government support

The UK's `sustainable polycentric' governance framework is based upon enabling the formation and establishment of sustainable business models (for a review see Davies et. al 2010) within those segments of the NIS targeted by the NIP. This has stimulated a widespread reform of the UK soft infrastructure system to militate against the underlying risks within infrastructure investment (HMT 2012, 2013). Academic (Besley 2013) and practitioner (see for example CBI 2013) research has demonstrated that the pre-NIP soft infrastructure system inflated costs structures due to the fragmentation of construction industry, complex procurement and planning rules (Helm 2009). The reform of the supporting institutional architecture of the NIS is focused on reducing construction cost, increasing the diversity of funding sources, effectively balancing risk and reward between public and private sectors (Helm 2011). The strategic objectives of such reforms are to fully adjust the NIS to enable it to respond to changes in public needs (Hall etc. 2012), to facilitate the delivery of projects on time and on budget (see Flyvberg 2007) and to lower the cost of procurement and increase the speed of planning (see for example NAO 2013b). An explicit goal has been to amend planning systems with the aim of reducing project cost by 15 per cent (£2-3 bn per annum). This is to be achieved through a planned pipeline of projects; reducing

uncertainty caused by infrastructure costs and improving the procurement process but also through increasing project planning skills in government and lower regulatory burdens (HMT 2010a).

Whilst such reforms can reduce costs within infrastructural business models linked to the NIP, there is a consensus that such cost savings are incidental to model sustainability. In public infrastructure – where monopolies have been a common governance system – business models reflect the time lags and risks between construction and operational phases. For the CBI (2015) amongst others, the anticipated risk allocation between public and private sectors within the NIP is stymying model sustainability. Whilst the state has committed £300 bn to NIP related projects to 2020 (HMT 2012) this is a maximum 20 per cent of funding needed. Moreover £100 bn of this money is focussed on specific projects that meet a narrow set of criteria namely that the project is commercially viable, can be started quickly, needs state guarantees and offers value for money for tax payers. Overall this suggests that sustainability for key projects will be limited on the current anticipated allocation of risk between public and private sectors. In the UK (and within the NIP) Greenfield investment has built around three models of state/non-state actor interaction: private finance with explicit public regulation and/or implicit public support; public resources and public-private partnerships (PPPs) (NAO 2010, 2011). PPPs – in their highly varied forms - have been common in Greenfield investment (especially within social infrastructure about 80 per cent of all PPPs) through risk apportioning between parties (Osborne 2002, Kee and Forrer (2008).

Table 4: UK Infrastructure Initiatives (Post 2010) – UK's Infrastructural Architecture

Initiative (date launched))	Function
Infrastructure UK (2010 -2016)	The Treasury based unit seeks to channel private investment in to UK infrastructure (merged into Infrastructure and Projects Authority from 2016)
Green Investment Bank (2012)	Funding (£ 3 bn) offered by government to enable channelling of private funds into infrastructure projects that support environmental sustainability.
UK Loan Guarantee Scheme (2012)	To make available £ 40 bn of loan guarantees on chosen infrastructure
Major Infrastructure Planning Unit (2011- 2016)	Based within the Planning Inspectorate the role is to fast track major infrastructure projects (merged into Infrastructure and Projects Authority from 2016).
National Planning Policy Framework (2012)	Simplify planning framework to make policy less complex.
Private Finance 2 (2012)	Reform of programme government becomes minority shareholder and process of contract negotiation speeded up and planning more transparent.
Centre for Protection of National Infrastructure (2007)	A government authority which provides protective security advice to businesses and organisations across the NIS.
Infrastructure Resilience Programme (2011)	Based within Cabinet Office, to enable public and private sector organisations to build the resilience of their infrastructure, supply and distribution systems to disruption from all risks (hazards and threats)
Major Projects Authority (2011)	The aim is to improve value for money from large projects.
Infrastructure Commission (2015)	The aim is to promote long term planning and greater time consistency in Infrastructure development.
Infrastructure and Project Authority (2016)	The aim is to combine overlapping government expertise in financing, delivery and assurance of major economic projects

The most widespread criticism made by both practitioners and academics (notably Helm 2013) is that that the NIP is not a coherent functionally systemic approach to the development of the NIS as its focuses on standalone projects. The political economy of a growth strategy in a period of endemic austerity has pushed to the front of the NIP those projects that are able to be started quickly with credible and sustainable business models. This reflects the aim for the NIP to be dominated by the private sector with minimal state resource. According to Helm (2013) local needs have over ridden national needs with little focus on the requirements of the national system creating the risk of spatial inconsistency. Traffic based business

models cannot be viewed in isolation as these are value systems whose sustainability is driven by traffic flows created by or flowing into other parts of the system. Whilst functional complexity was an explicit theme within the NIP in 2011, its prominence has been downplayed within successive statements which focus on creating common frameworks for managing and planning interdependencies.

Time consistency (or a perception of a lack of) has been a persistent theme of discourse on infrastructure policy. Multiple parties (academic, political and business) have all sought to de-politicise infrastructure policy by promoting institutional frameworks that stand aside from the political cycle (see for example Besley et al. 2013). Whilst not making the process apolitical, limiting policy risks in the infrastructure means militating against policy discontinuities and arguing for a 25-30 year time frame for strategy completion. Whilst the intent of the NIP – as a strategic plan – was to offer greater time consistency (a process aided in part by a series of independent regulators), it has in practice proved elusive. This is due to the absence of any consensus within the political market for many of the themes engendered within the plan. For example, there is emergent political resistance to financing 70 per cent of cost of the NIP through user charges against a background where such user charges have already risen substantially; a process especially evident in energy infrastructure. Evidence from industry (CBI 2013), the regulator (Ofgem 2014) and government (PAC 2014) indicates that 60 per cent of investors are still deterred by a lack of policy clarity and the risk of the politicisation of the process. This is despite a consensus on the need for re-infrastructuring. This situation is compounded by the discontinuities in capital programmes created as political cycles evolve which can often allow local, short term needs to override longer term, systemic requirements. This problem is further heightened by the absence of forums through which stakeholders can interact (Coelho et. al 2014). This was typified by the shift of stance on

some prioritised projects within the NIP which - under political pressure (due to marginal electoral constituencies) - have been brought back within the public sector budget. Time inconsistency created by the inability of the state to reconcile the needs of the infrastructural business models sought by the NIP with the context set by economic austerity has also created policy dilemmas. The UK Government initially attempted to reconcile this inconsistency with the establishment of a National Infrastructure Commission in 2015 with statutory status. However it has since backtracked on this strategy leaving the body with a merely advisory role (IPA 2016). The most notable inconsistency created by austerity has been the limited government finance to support higher risk projects. Indeed an immediate casualty of austerity was the sharp reductions in government capital expenditure (NAO 2015). This lead to what is seen by businesses as an unsustainable re-allocation of risk between public and private bodies (CBI 2013).

There is also ambiguity on the inter-relationships between the different strands of the UK's infrastructure strategy. This ambiguity is sourced from the fact that the relationship between those projects promoted within the NIP and those infrastructures deemed critical to the sustenance of the UK state is opaque (CPNI 2010). Given the government's desire to build them, it is evident (though left unstated by policy discourses) that NIP projects are key parts of the UK Critical Infrastructure System (CIS). Whilst resilience is a theme embedded within the NIP (adding 1-2 per cent of the cost of a project) (HMT 2010), the issue of sustainability (as defined above) is missing. The overlap between projects within the NIP and CIS raises issues of the creation of sustainable business models for critical infrastructure. It also leaves open to question the extent to which the state would either underwrite or seek to intervene should these systems veer towards unsustainability. The UK has shown on occasions that it is

prepared to contemplate state ownership for an asset where the business model has proved unsustainable[8]. Again this issue is currently left unresolved in the NIP.

In practice, criticality and sustainability are often reconciled through various forms of PPPs. However these devices are used more for social than economic infrastructure. Where PPPs have been used in the provision of economic infrastructure they have proved highly controversial. Hare (2013) alleges poor choices by - and poor value for - government which did little to cure the under-investment in the NIS. Within the context of Public Finance Initiative (PFI) (the UK's flagship PPP initiative), polycentrism has not been as marked as planned with many PFI contracts only attracting one or two bidders. This pattern has been reciprocated within the NIP where, in a number of PFI projects, incumbents (such as in the BT exemplar noted above) (NAO 2013b) have been given preference. Additionally, issues over criticality have raised concerns over the sustainability of globality within the NIS. Whilst the government maintains an open system for investment and ownership and NIS, there have been concerns expressed over aspects notably over the UK's concerns over Chinese involvement in its critical infrastructure[9](CEBR 2014).

The focus on the NIP as a growth catalyst underplays the role that the NIS plays in state territoriality with the growth focus seeming to restrain the other interlinked territorial needs

[8] The most evident examples of this were Railtrack in 2002 (which was taken over by the government as it faced financial pressures due to the legacy of the Hatfield Rail Crash and the spiraling cost of the upgrade of the West Coast line) and British Energy in 2004 which also required government support as energy prices slumped. Furthermore on broader issues of `critical infrastructure', the government bailout of parts of the banking sector in the aftermath of the 2007/08 indicated a preparation to nationalize businesses whose failure would do damage to the UK's social, political and economic system.

[9] In 2013, the UK Intelligence and Security Committee raised concerns over Huawei's investment in the UK's infrastructure (ICS 2013) and, in 2016, the Government delayed approval of the involvement by the China General Nuclear Power Corporation in a power station project. Whilst both were ultimately approved it did signal that system globality was not unquestioning. Though in late 2016, the government did approve the sale the national gas grid to a group of foreign investors.

of an NIS of security, integration and control. The establishment of sustainable infrastructural business models - which lie at the core of the NIP - are challenged with meeting the multi-faceted requirements of the NIS for the territorial state but the political economy of the NIP is about what can happen quickly rather than what needs to happen strategically (PAC 2014). After five years, it is evident that the NIP has not lived up to expectations. Between 2010 and 2014, investment has fallen both in nominal terms (by 4.5 per cent) and in terms of its share of GDP to 1.4 % (which is below the long term historical average and the government target of 3 per cent) (Pisu et al. 2015). Moreover the nominal rise in investment has mainly been in equity and to a lesser extent brownfield investment and not the Greenfield investment that lies at the core of the NIP. In this area the UK state – up to 2015 – remains dominant (OECD 2015). This reflects that under the current proposed configuration of risk between public and private sectors viable infrastructural business models for projects within the NIP remain elusive.

Conclusions

The emergence of the polycentric NIS poses governance challenges for the state as it seeks to steer a system it largely no longer owns in a direction that addresses both its needs and those of the increasingly diverse owners of the system. This article has drawn together a diverse stream of literature that encapsulates those themes that shape the governance of infrastructure at the system level. Whilst not exhaustive, the material does synthesise the main themes shaping the capability of the state to infrastructure to ensure these assets operate as an effective tool of territoriality. Importantly this work does not exclude the state as an actor but that its role is adapting as the polycentric system is embedded. Thus whilst the state will

continue the direct provision of parts of the NIS, in other segments it will seek to steer outcomes through a mix of regulation, subsidy or other forms of public-private partnership.

The UK experience (as perhaps the most advanced polycentric system) since the launch of the NIP in 2010 offers insights into the difficulties within a national infrastructure strategy of reconciling territoriality and polycentrism. Set against a background of austerity and an embedded logic of the competition state, the UK NIP (as indeed is its successor the NDIP) was more a growth strategy than a holistic framework for the development of the NIS. As a result it is – as a strategy for the NIS – incomplete. The model of sustainable polycentrism which is driving the strategy seems flawed with funds for Greenfield investment lacking and with key issues of consistency, criticality and complexity not being addressed in any systematic fashion. This suggests that as a strategy for its NIS, the NIP is at best incomplete. Of course, the UK is but one system and further analysis of these drivers across other similar systems is required not so much to test the validity of the framework but to assess how states are reconciling territoriality and polycentrism through adaptation in governance.

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